

New automation capability of the NDACC/TOLNet tropospheric ozone lidar at JPL - Table Mountain Facility

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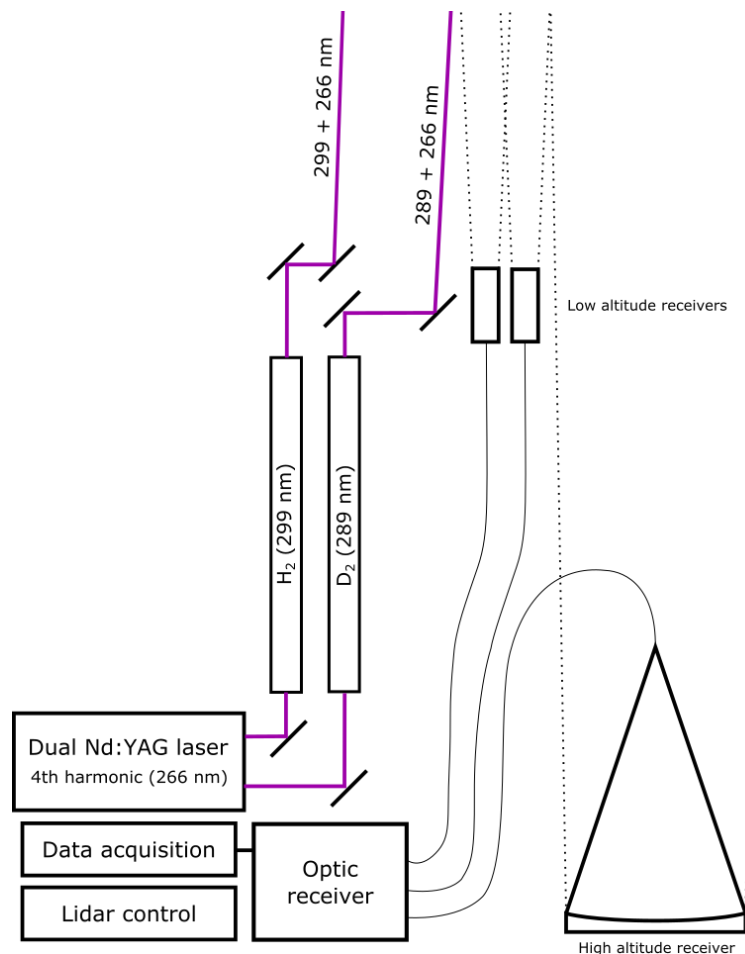
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- **Lidar activities at TMF / Tropospheric ozone lidar setup**
- **Tropospheric ozone lidar automation**
 - *Hardware*
 - *Acquisition software*
- **Very-near-range receiver**
 - *Setup*
 - *Validation*
- **Summary**

Highlights

- *Original design intended for NDACC operation, with start date of 1999*
- *Measurement schedule: typically 3-4 times per week, 2 hours per night, total 3000 profiles since 1999*
- *More recent developments (since 2013) for 'TOLNet', with added daytime measurements*
- *Validation took place August 2016 (SCOOP Campaign)*

System setup (before update)



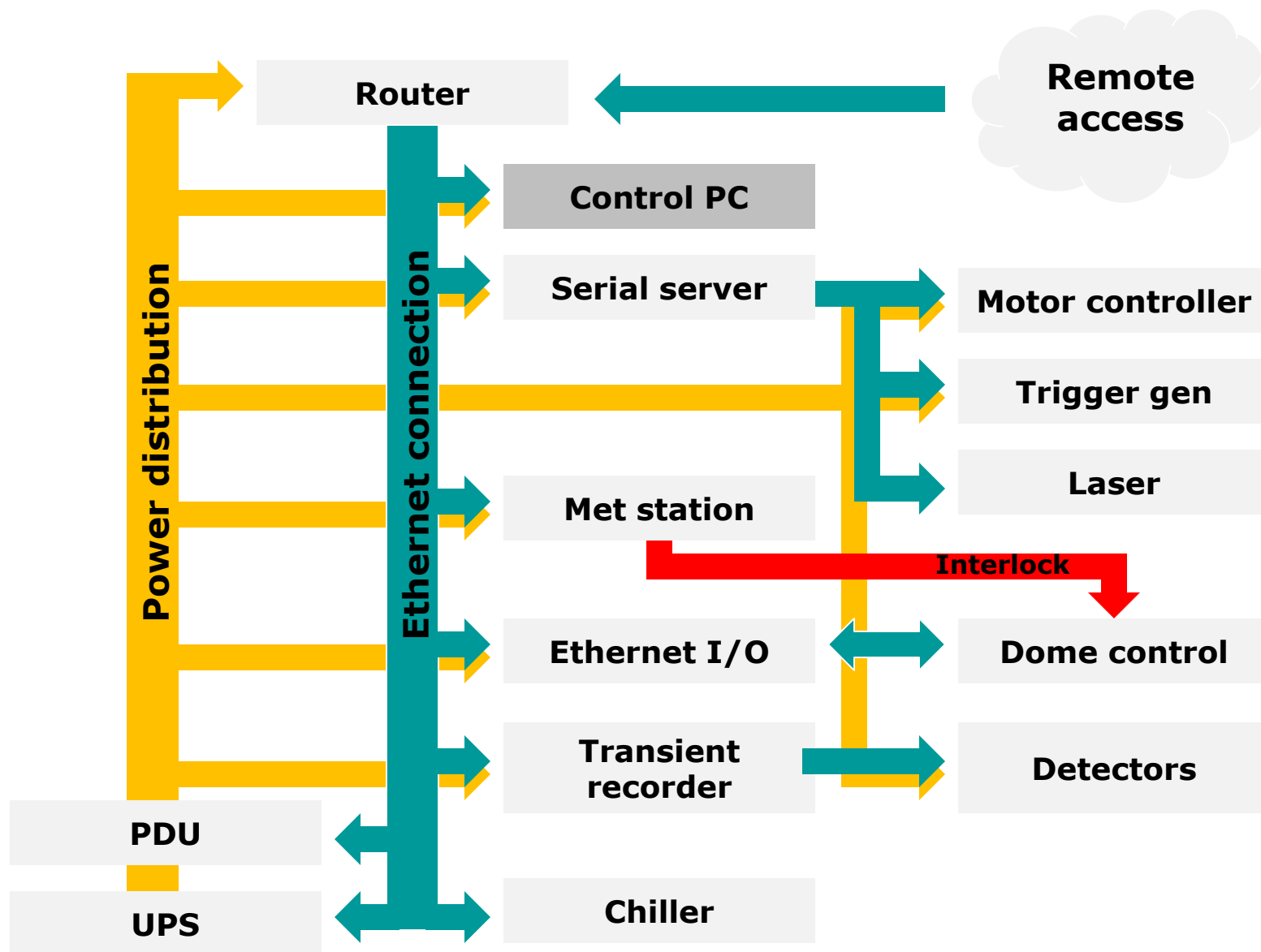
McDermid, I. S., Beyerle, G., Haner, D. A., and Leblanc, T.: Redesign and improved performance of the tropospheric ozone lidar at the Jet Propulsion Laboratory Table Mountain Facility, Appl. Opt., 41, 7550-7555, 2002.

- **Design criteria / Required features**

- *Modular approach for easy tests and modifications.*
- *Hardware interlocking for the lidar hatch in case of rain.*
- *Easy replaceable control PC (i.e. no special interface or acquisition cards installed on the PC).*
- *Ability to reset every component remotely.*

Key implementation features

- *Ethernet as the preferred technology for communication with the different peripherals*
- *Power distribution based on Ethernet controlled power distributions units (PDUs).*



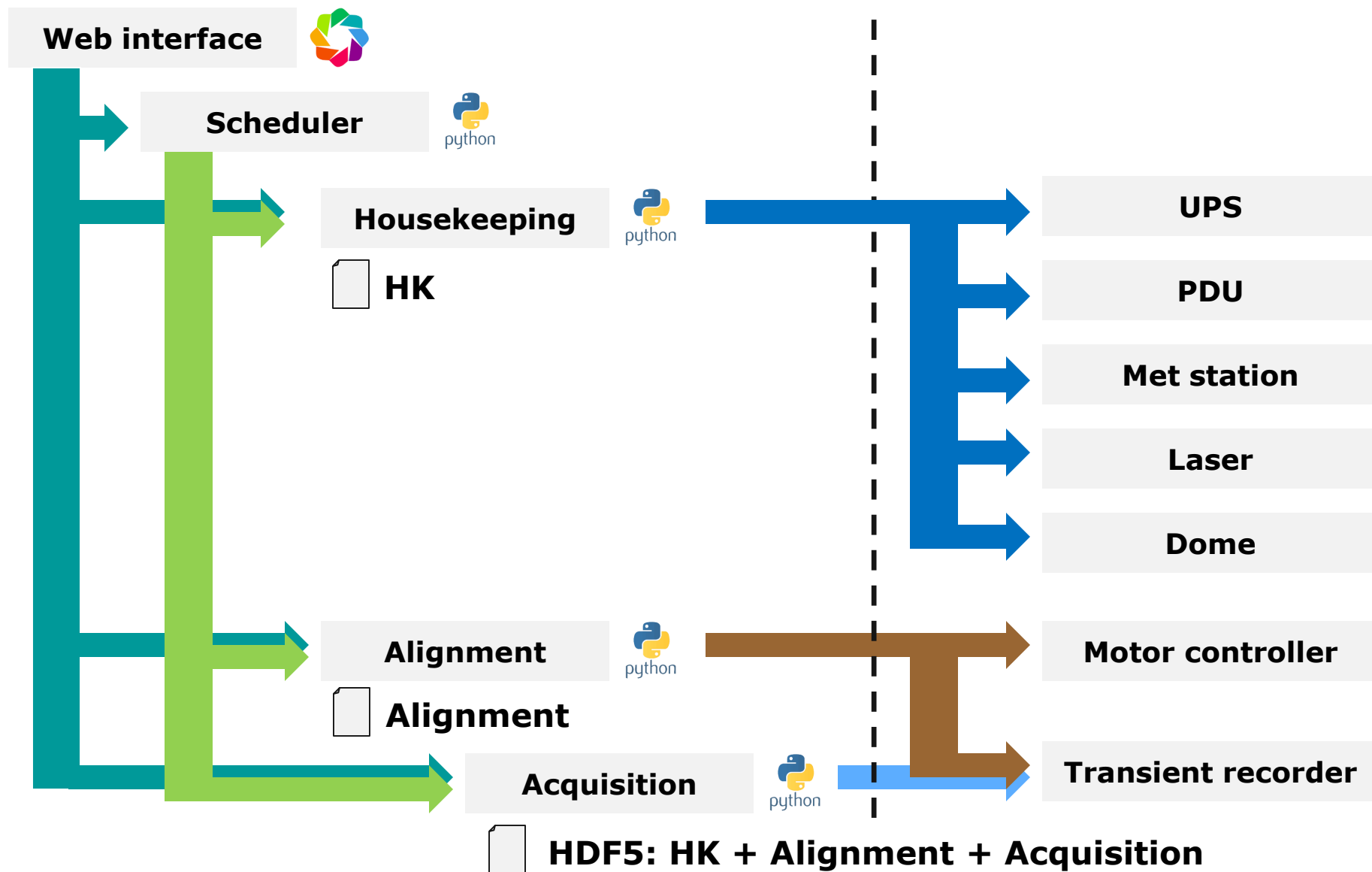
- **Design criteria / Required features**

- *Modular approach for easy tests and modifications.*
- *Portable to other lidar systems at TMF.*
- *HDF5 data storage (1 minute time resolution).*
- *Easy remote access.*
- *Email report on acquisition start and end.*
- *Detailed system status logging*

- **Implementation**

- **Python + Bokeh** (interactive visualization library).
- *Free and open source software.*
- *Code divided in five modules (**scheduler, housekeeping, alignment, acquisition, and web interface**). Connection between modules is implemented with sockets.*
- *Interface running on a **web browser**.*





Bokeh Application - Mozilla Firefox

Bokeh Application x +

localhost:5006/web_interface_v2

Tropospheric ozone lidar

Schedule Housekeeping Alignment Acquisition System setup System log

Start schedule Stop schedule Scheduler not started

Schedule Selected program

#	Date	Program	Status	#	Date	Command	Status
0	2018-02-06 19:49:00	program.csv	Regular	0	00:00:00	HK MSG Started	Programmed
1	2018-02-07 04:00:00	program2.csv	Regular	1	00:00:05	HK CHL On	Programmed
2	2018-02-07 19:31:00	program.csv	Regular	2	00:00:10	HK RLY 0.5 0	Programmed
3	2018-02-08 02:30:00	program2.csv	Regular	3	00:00:50	HK RLY 10 3 4	Programmed
4	2018-02-08 20:52:00	program.csv	Regular	4	00:01:10	HK PDU 1 On	Programmed
5	2018-02-09 03:07:00	program2.csv	Regular	5	00:01:15	HK PDU 2 On	Programmed
6	2018-02-09 20:33:00	program.csv	Regular	6	00:01:20	HK PDU 3 On	Programmed
				7	00:01:25	HK PDU 4 On	Programmed
				8	00:01:35	HK PDU 5 On	Programmed
				9	00:01:40	HK PDU 6 On	Programmed
				10	00:01:45	HK PDU 14 On	Programmed
				11	00:01:50	HK LSR On	Programmed
				12	00:01:55	Acq Start NoStore 5	Programmed
				13	00:16:30	Alg Start 1 1 5000 1000 150	Programmed
				14	00:19:00	Alg Align Centroid 500	Programmed
				15	00:19:15	Alg Stop	Programmed
				16	00:19:30	Alg Start 1 2 5000 1000 150	Programmed
				17	00:22:00	Alg Align Centroid 500	Programmed
				18	00:22:15	Alg Stop	Programmed
				19	00:22:30	Alg Start 0 3 5000 1000 150	Programmed
				20	00:25:00	Alg Align Centroid 500	Programmed
				21	00:25:15	Alg Stop	Programmed
				22	00:25:30	Alg Start 0 4 5000 1000 150	Programmed
				23	00:28:00	Alg Align Centroid 500	Programmed
				24	00:28:15	Alg Stop	Programmed
				25	00:28:30	Acq Stop	Programmed
				26	00:28:45	Acq Start Store 5	Programmed
				27	01:28:45	Acq Stop	Programmed
				28	01:29:10	HK PDU 1 Off	Programmed

Add program

Date: Mon Feb 12 2018

Start time (hours): 0

Start time (minutes): 0

Program: program.csv

Add task Remove task

Bokeh Application - Mozilla Firefox

Bokeh Application

localhost:5006/web_interface_v2

Search

Tropospheric ozone lidar

Schedule

Housekeeping

Alignment

Acquisition

System setup

System log

Chiller control

Chiller on

Chiller off

Chiller status: Off
Leaving: 51.8
Entering: 54.8
Pump pressure: 0.1

Laser control

Laser on

Laser off

Laser shots: 18413298

Dome hatch control

Open hatch

Close hatch

Stop hatch

Closed

Telescope hatch control

Open hatch

Close hatch

Closed

PDU control

PDU 1 On

PDU 1 Off

PDU 1 Off

PDU 2 On

PDU 2 Off

PDU 2 Off

PDU 3 On

PDU 3 Off

PDU 3 Off

PDU 4 On

PDU 4 Off

PDU 4 Off

PDU 5 On

PDU 5 Off

PDU 5 Off

PDU 6 On

PDU 6 Off

PDU 6 Off

PDU 7 On

PDU 7 Off

PDU 7 On

PDU 8 On

PDU 8 Off

PDU 8 On

PDU 9 On

PDU 9 Off

PDU 9 On

PDU 10 On

PDU 10 Off

PDU 10 On

PDU 11 On

PDU 11 Off

PDU 11 On

PDU 12 On

PDU 12 Off

PDU 12 On

PDU 13 On

PDU 13 Off

PDU 13 On

PDU 14 On

PDU 14 Off

PDU 14 On

PDU 15 On

PDU 15 Off

PDU 15 On

PDU 16 On

PDU 16 Off

PDU 16 On

Met conditions

Wind speed [m/s]: 6.55
Wind direction [deg]: 210.00
Humidity [%]: 95.00
Temperature [°C]: -2.70
Pressure [mbar]: 763.25

UPS Status

Status of UPS: Online, Smart Trim
Last Transfer: Detection of distorted input
Runtime Remaining: 3 hr 26 min 19 sec
Output Voltage: 110.2 VAC
Output Frequency: 60.0 Hz
Output Watts Percent: 4.7 %
Input Voltage: 120.9 VAC
Input Frequency: 60.0 Hz
Battery Temperature: 25.6 C, 78.0 F

Interlock control

Interlock on

Interlock off

Bokeh Application - Mozilla Firefox

Bokeh Application

localhost:5006/web_interface_v2

Search

Tropospheric ozone lidar

ScheduleHousekeepingAlignmentAcquisitionSystem setupSystem log

Start alignmentStop scanStop alignmentAlignment not started

Channel289H

Axis3

Range6000

Step1000

Alignment

H 1 [m]500

H 2 [m]1000

H 3 [m]2000

H 4 [m]4000

H 5 [m]8000

Centroid0

Alignment range [m]3500

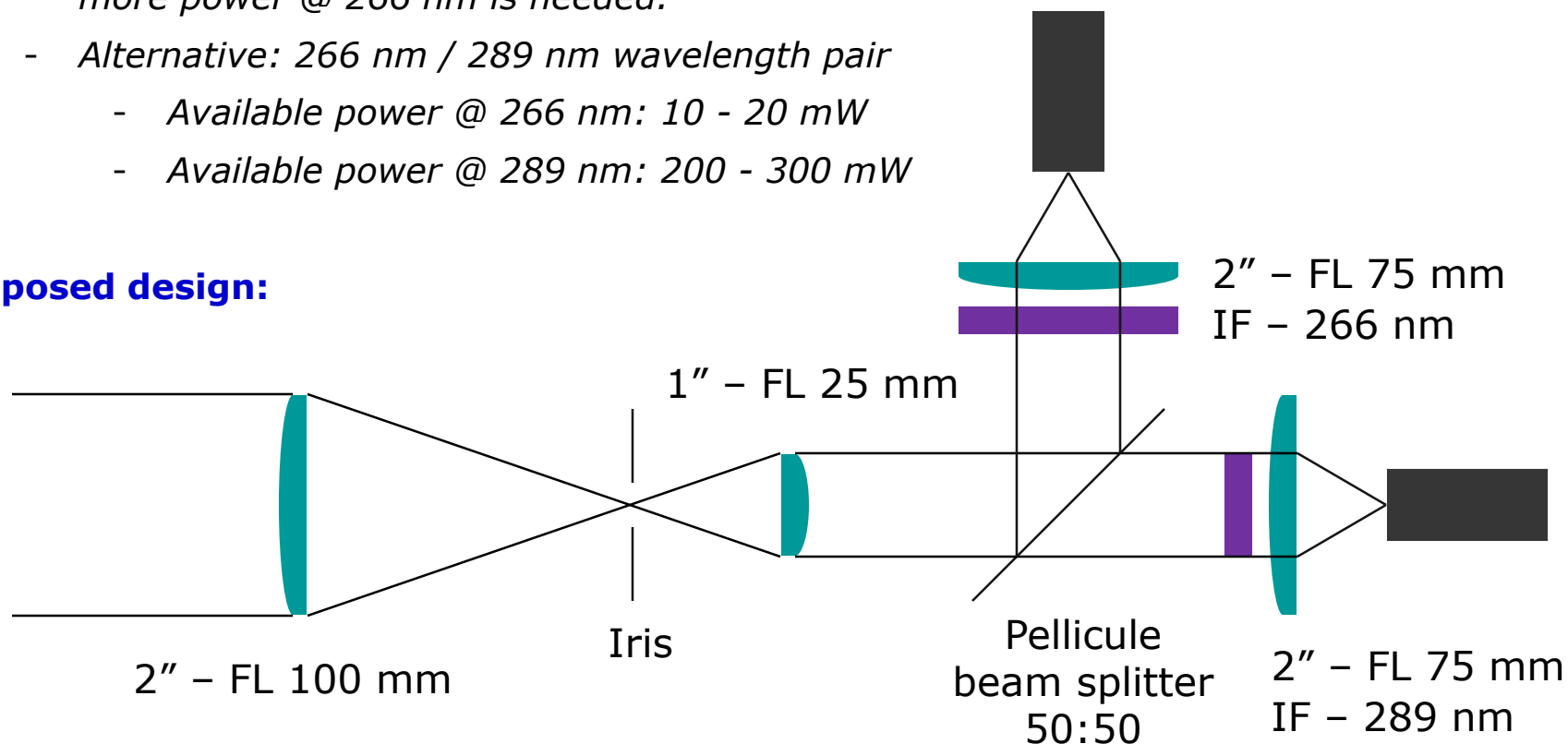
Calculate centroid



• Design criteria / Required features

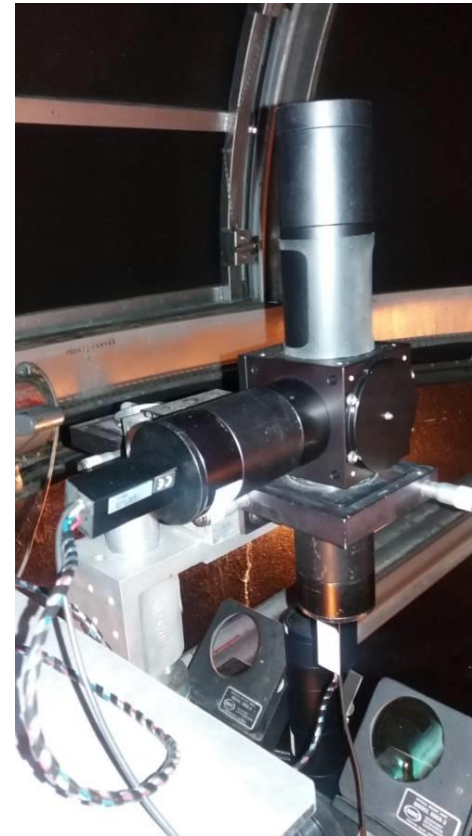
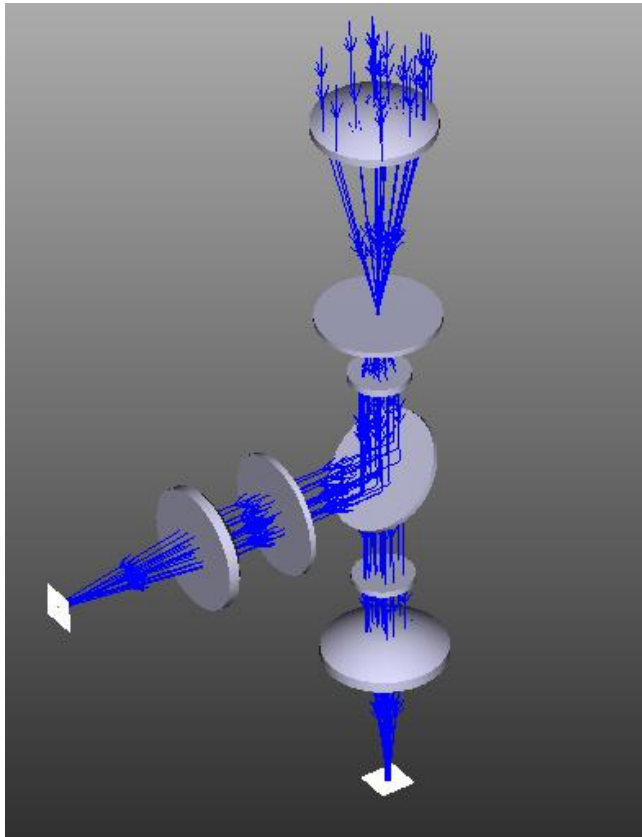
- Range: 100 - 1000 m
- Signal dynamic range: 3 orders of magnitude (assuming no extinction, only r^2 dependency)
- Originally Raman channels were planned, but the available power is not enough. Around 10 times more power @ 266 nm is needed.
- Alternative: 266 nm / 289 nm wavelength pair
 - Available power @ 266 nm: 10 - 20 mW
 - Available power @ 289 nm: 200 - 300 mW

Proposed design:

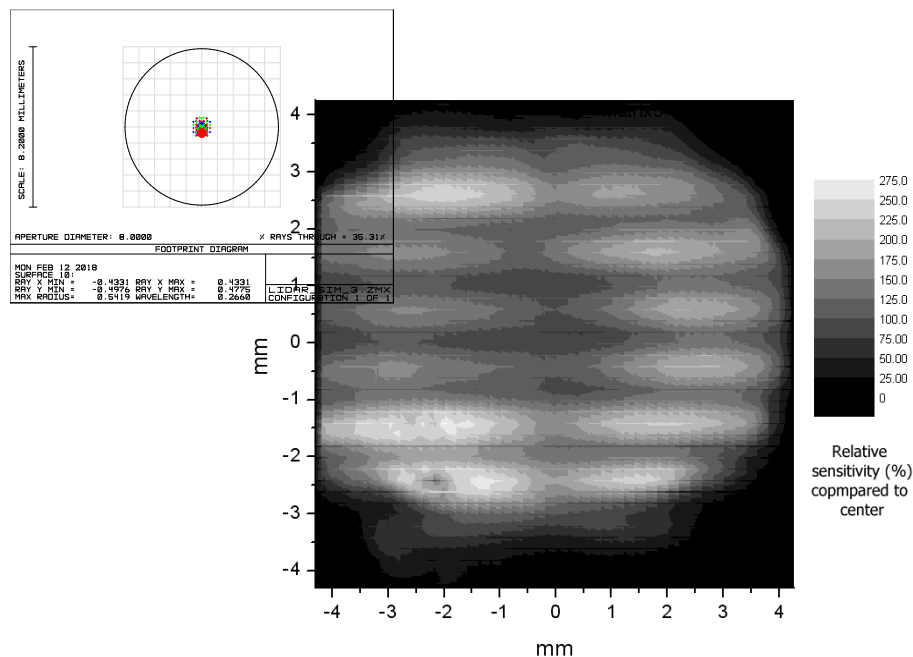


- **ZEMAX Simulation / Construction**

- *General evaluation of the setup (overlap, AOI on interference filters)*
- *Analysis of detector surface sensitivity for very near measurements (below 100 m)*



PMT Surface



Based on 10 cm separation between receiver and transmitter

Blue -> Inf, 0 mm

Green -> 100 m, 0.15 mm

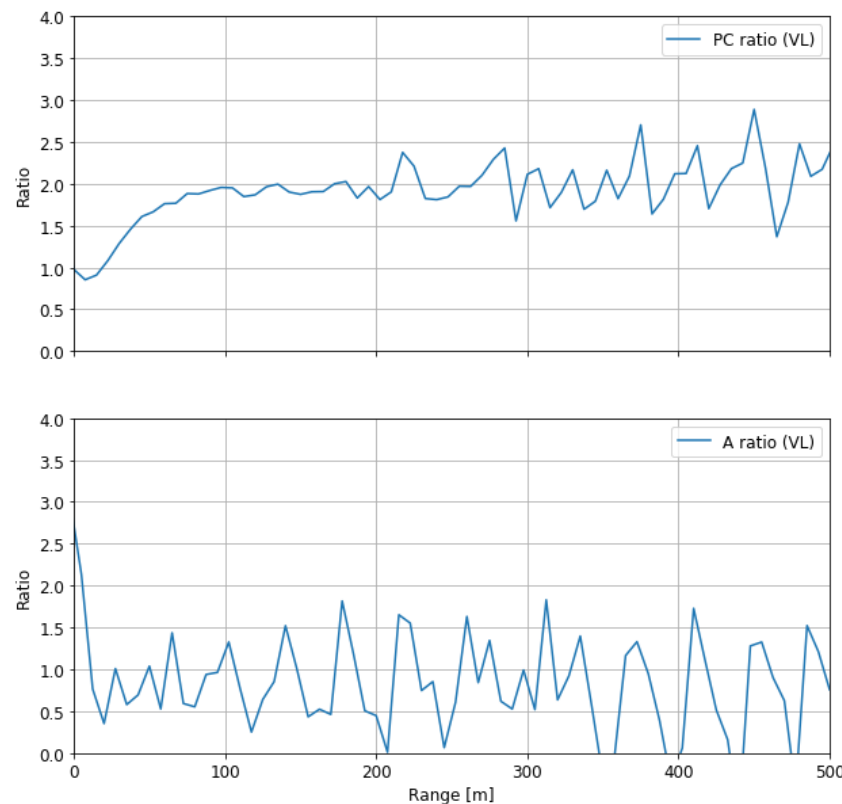
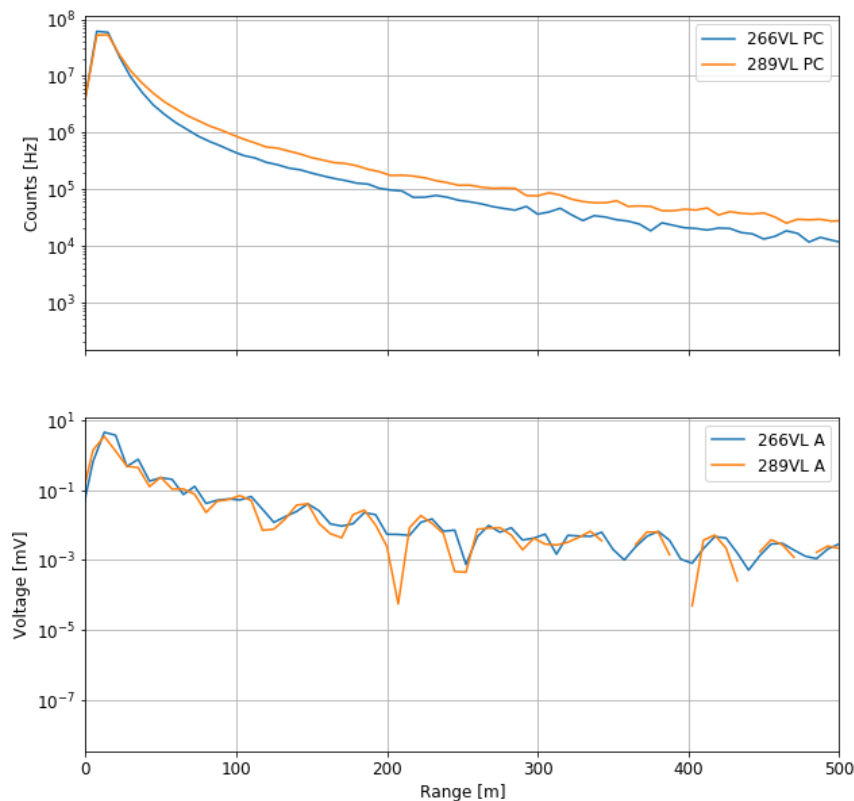
Red -> 50 m, 0.3 mm -> up to **25% more signal!**

V. Simeonov et al., Influence of the Photomultiplier Tube Spatial Uniformity on Lidar Signals, Appl. Opt. 38, 5186-5190 August 1999.

Freudenthaler, V., 2004: Effects of spatially inhomogeneous photomultiplier sensitivity on lidar signals and remedies, Proc. 22. ILRC, Matera, Italy, ESA SP-561, 37-40.

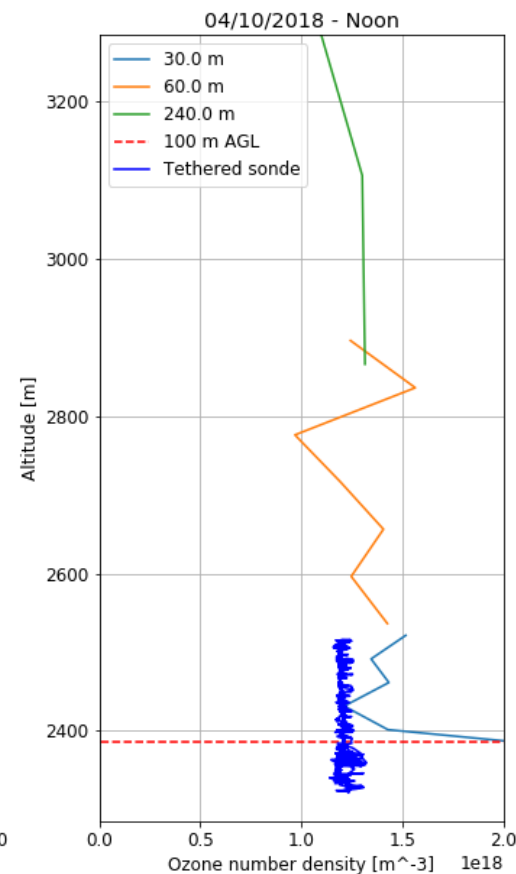
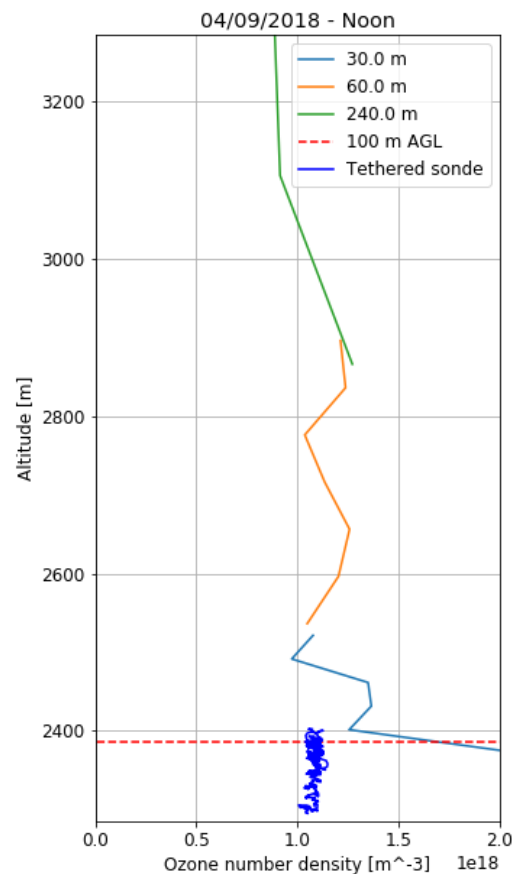
• Estimation of the differential overlap/gain factor [G]

- *Measurement of the differential overlap function/PMT sensitivity between the two receiver arms using two 289 nm IF filters.*
- *OD3 was added in front of the receiver to avoid saturation effects on the signals in the range of interest.*



• Validation

- *A tethered balloon with an ozone sonde is currently being used to validate the measurements of the new very-near-range receiver.*
- *Only measurements on very calm conditions can be carried out with the tethered balloon.*
- *Overestimation in the ozone lidar retrieval is likely to be partially due to aerosols, as typically found in the ABL (Error term B).*



- **Lidar automation**

- *The lidar is currently operating twice a day in autonomous mode.*
- *Some functions, like laser power monitoring and cloud coverage monitoring still have to be implemented.*

- **Very-near-range receiver**

- *First tests on the receiver overlap were conducted, giving promising results.*
- *Issues with the analog channels need to be solved in order to cover the complete receiver range with good SNR.*
- *We are in the process of getting a UAV-borne ozone sonde. This would allow us to operate not only under very calm wind conditions.*
- *The range could be further lowered with postprocessing, by applying a correction factor based on the estimation of the differential overlap/gain factor.*

- **Issues**

- *Due to the high dynamic range of the signal, analog and photocounting signals have to be used.*
- *The analog signals exhibit artifacts on the first bins. This artifacts were identified to be caused by transient recorder. Other analog transient recorder has to be used.*